Trade openness, technological shocks and spillovers in the labour market: A GVAR analysis of the US manufacturing sector*

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Abstract

In this paper, we seek to analyse the extent to which disproportionate labour market weakness in the US manufacturing sector over the last decades has derived from increasing trade openness and technological change. The econometric approach involves an application of the recently developed global VAR (GVAR) methodology of Dées, DiMauro, Pesaran, and Smith (2005) to 12 manufacturing sector industries over the period 1977-2003. Such an approach allows not only for the empirical derivation of the impact of common shocks (such as increased trade openness and technology) on US employment and wage formation, but also for an analysis of intra-industry spillovers. Beyond a standard set of labour market variables and and exogenous factors, manufacturing-wide variables for each sector—measured as a weighted average of other sectors— are included. Impact elasticities indicate strong intra-sectoral linkages for employment and capital stock formation, contrasting with weak linkages for what concerns real wages and productivity. An analysis of generalised impulse responses indicate that trade openness negatively affects real wages and positively affects employment, whilst technology appears to positively affect both real wages and employment. Moreover, there is evidence of positive spillovers of employment and wage shocks across industries.

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1 Introduction

In recent years, developments in the international economy have sparked renewed concerns about the effects of international trade on the labour market developments of industrialised countries, particularly for what concerns labour-intensive and low-skilled sectors. At the same time, evidence of accelerating technological progress has also exerted some influence on labour market developments of these economies.

For the US, a sectoral breakdown of the labour market reveals that in recent years, employment weakness has been most pronounced in the manufacturing sector which has more generally been in a position of relative secular decline when assessed against overall nonfarm employment since the mid-1970s. As illustrated in Chart 1b, the share of the manufacturing sector as a percent of GDP has been steadily falling in conjunction with a falling share of both manufacturing employment and wages as a percent of total non-agricultural employment. Since the mid-1990s, manufacturing sector employment has been consistently more sluggish than aggregate employment developments, which has been correlated with a sizeable expansion in the trade deficit in goods and services (Chart 1a) along with strong productivity gains (Chart 1d). At the same time, relatively strong productivity gains in the manufacturing sector compared with the overall economy have been partly—but not entirely—reflected in relatively higher real compensation per hour in the manufacturing sector (Chart 1c).

[INSERT CHART 1]

Two main arguments for structural weakness in industrialised countries' manufacturing sector labour market outcomes have been advanced. The first has been linked to the role of skill-biased technological change. Specifically, the argument is that an autonomous surge in technical progress has involved an upward shift in productivity growth given improved capital and management innovations, which has generated sectoral reallocation of production biased against primarily low-skilled workers in developed economies. The second argument involves the attrition of low-skilled and/or low-wage jobs in certain sectors to developing countries. Specifically, growing imports of labour-intensive manufactured goods from developing countries have been accompanied by a growing phenomenon of global corporate restructuring involving more intense use of global subsidiaries and outside contractors and greater mobility of capital. The above strict dichotomy between trade and technology, however, is somewhat artificial given that the two phenomena have become progressively intertwined. As noted in Hoekman and Winters (2005), it is increasingly recognised in recent literature that trade is a

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1 Policy concerns have been most recently illustrated by a debate in Europe and the US concerning the possible imposition of restrictions on textile imports from China to protect domestic producers.

2 As noted by Bernard, Jensen, and Schott (2006), this overall decline masks substantial reallocation of activity across industries within manufacturing, and across plants within industries.

3 Separate arguments unrelated to trade or technology is that (1) there may have been a more general reduction in the share of manufactured goods in consumption through time in favour of services given demographic changes in advanced economies, such as the consumption of more medical care and the outsourcing of household tasks to various service providers (see CongressionalBudgetOffice (2004)) or (2) the “splintering” or “fragmentation” of services from manufacturing, whereby part of the manufacturing value added is contracted out to a separate firm and re-classified as a service (see Bhagwati, Panagariya, and Srinivasan (2004)).
channel for technology diffusion and adoption, both directly (through imports of capital goods) and indirectly (through pressure on firms exposed to trade to innovate).

While both trade and technology would be expected to benefit the population of both emerging and developed economies in the long-run through lower prices and higher living standards along with pecuniary gains from specialisation, in the short-term some adjustment costs could be related to distributional effects associated with sectoral reallocation of labour. Such adjustment costs may arise from frictional unemployment associated with sectoral reallocation of displaced workers and any associated need for retraining (these costs could be higher in the manufacturing sector than elsewhere as job-specific or industry-specific skills are likely more important in manufacturing firms while service-oriented skills like accounting or payroll may transfer across firms and industries more easily) and from public policies that impede the mobility of labour by slowing-down the transfer of resources from declining to expanding activities as outlined in Kongsrud and Wanner (2005). Policies to impede structural adjustment could be harmful in the long-run insofar as they act as barriers to service-sector expansion and may hamper the absorption of resources released by trade liberalisation and technological advances. In empirically assessing such impacts, research to date has offered no conclusive estimates of the effects of trade liberalisation and technological progress on labour market outcomes.

In this paper, we seek to quantify the extent to which disproportionate weakness in US manufacturing labour market outcomes has derived from common shocks—notably increasing trade openness and technological change—and intra-sectoral spillovers on the basis of the recently developed global VAR (GVAR) methodology of Dées, DiMauro, Pesaran, and Smith (2005). The analysis is based on a panel of twelve sectors of manufacturing applied to a system comprised of four endogenous variables (employment, real wages, productivity and capital stock) along with several exogenous variables (including common shocks of trade openness and R&D as a proxy for technological progress; while for each sector, manufacturing-wide variables measured are constructed as weighted average of other sectors).\(^4\) Such a framework is able to account for various transmission channels of trade openness and technology shocks to labour market outcomes, including common shocks to the manufacturing sector as well as the spillovers of idiosyncratic shocks across sectors.

The paper is organised as follows. We preface the analysis with a brief overview of the relevant literature in Section 2. Next, we proceed to the econometric estimation in Section 3. Some concluding remarks are then drawn in Section 5.

2 The impact of trade and technological change on the US labour market: a brief review of the literature

The two most widely cited theories linking trade to labour market outcomes are those of Heckscher-Ohlin-Samuelson and Stolper-Samuelson. The former theory posits that countries export goods that intensively utilise the factors of production with which they are relatively abundantly endowed, and import goods that use intensively factors that are relatively scarce at home. The latter theory posits that when import-competing

\(^4\)In this sense, whilst the ‘GVAR’ nomenclature is retained, the term ‘global’ applies to manufacturing sector as a whole—and not other countries/regions—in contrast to the DdPS global model application.
goods are relatively labor-intensive, protection unambiguously raises real wages (see Neary (2004)).

Frictions and stickiness may alter the predictions of such models, which are assumed to operate over a time period that is long enough to allow complete detachment of workers and capital from their original sectors. In the long run, trade would be expected to benefit the population of both emerging and developed economies through higher living standards, more product choice and pecuniary gains from specialisation. In the short run, however, some adjustment costs could be related to distributional effects associated with sectoral reallocation of labour. Such adjustment costs may arise from, inter alia, (1) frictional unemployment associated with sectoral reallocation of displaced workers and any associated need for retraining; and (2) public policies that impede the mobility of labour by slowing-down the transfer of resources from declining to expanding activities. These costs could be higher in the manufacturing sector than elsewhere as job-specific or industry-specific skills are likely more important in manufacturing firms while service-oriented skills like accounting or payroll may transfer across firms and industries more easily.

Various approaches have been followed in the empirical validation of the above theories. A first strand of the literature has involved factor content calculations, whereby trade flows are analysed to compute the factor content of imports less that of exports to evaluate the net impact of trade on labour markets – such as Gomez-Salvador, Hiebert, Maurin, and Vansteenkiste (2006), Baily and Lawrence (2004), Sachs and Shatz (1994), Wood (1995) and Wood (1998). A second strand has involved econometric analysis, such as Revenga (1992) and Grossman (1987), whereby it is empirically tested whether increasing import competition can be a major factor behind declining employment and sluggish real wage growth in industrialised economies. A third strand has been more eclectic, involving inter alia general equilibrium HOS models of trade, analysis of input mixes at the industry level given input mix changes in production as trade is liberalised, and the role of prices (e.g. the evolution of commodity prices over time).

Whilst several studies find evidence that the demand for labour – particularly unskilled – may have become more elastic as a result of enhanced international openness in developed economies, the literature has pointed to only a limited direct impact of trade on wages and/or employment in developed economies. Such findings, however, must be tempered by the fact that trade and technological progress may be inextricably linked, thereby introducing an indirect effect of trade on labour market outcomes. As pointed out in Wood (1994), Wood (1995), Wood (1998), Anderton and Oscarsson (2002), and Thoenig and Verdier (2003), international competition may lead firms in the advanced economies to raise productivity by pursuing “defensive innovation”, including pressure on firms to innovate and/or alter the skill-intensity of production in response to a higher degree of trade openness. Moreover, trade may constitute a form of “technology transfer”, i.e. convergence in technical efficiency within individual countries over time.\(^5\)

\(^5\)A very recent contribution, Bernard, Jensen, and Schott (2006), looks at the role of international trade in the reallocation of U.S. manufacturing within and across industries.

\(^6\)See Cameron, Proudman, and Redding (2005) for a recent empirical investigation of such effects between the US and the UK, with the finding that international trade raises rates of UK productivity growth through technology transfer but not innovation. See Keller and R. Yeaple (2005) for the case of the US, where it is found that foreign direct investment (FDI) spillovers have a significant role in boosting productivity growth in the manufacturing sector, whereas the case for import-related technology
Within the above context, a technology shock can either negatively or positively affect labour market outcomes through trade, as trade may induce firms to successfully introduce productivity-enhancing technologies which do not have a definite positive or negative ex-ante labour market impact. On one hand, as noted in Amiti and Wei (2005), a positive technology shock may result in higher demand for labour due to scale effects, whilst higher productivity can lead to lower prices, generating further demand for output and labour given associated competitiveness gains. On the other hand, higher productivity can translate into job losses as the same amount of output can be produced with fewer inputs, whilst lower prices of imported inputs could lead to substitution away from domestic labour. Complicating matters further, trade does not have a clear causal effect on productivity. Whilst frictions associated with the adjustment to trade shocks may imply short-term labour market impacts which correlate with productivity, the causality may go in the other direction due to a composition effect, whereby more productive firms become better exporters.

Ultimately, a lack of clear theoretical or empirical findings showing a definite impact of trade and technology on labour market outcomes motivates further empirical work on the issue. Considering the interrelations between note only key labour market variables — i.e. wages and employment — but also trade and technology, an systems analysis also analysing dynamics induced by shocks is warranted.

3 Econometric evaluation of the effects of trade openness on US employment and wage dynamics

In this section we rely on the GVAR framework of Dées, DiMauro, Pesaran, and Smith (2005) and Pesaran, Schuermann, and Weiner (2004) in order to gauge the employment and wage effects of trade openness and technological change in a coherent system. This model explicitly allows for interdependencies that exist between sector and manufacturing wide factors, allowing for an analysis of the industry effects of common shocks as well as an assessment of spillovers from industry-specific shocks.

We start this section by first explaining the empirical set-up and model. In a next step, we present the unit root and cointegration test results for the sector-specific models, to then move to the contemporaneous effects the other sectors developments have on sector-specific employment, real wages, productivity and capital stock. This framework then enables us in the next section to analyse generalised impulse responses.

3.1 Empirical setup and model

The model developed in this paper covers 12 US manufacturing sectors classified according to the ‘International Standard Industrial Classification’ (ISIC) revision 3.9 The transfers has been less clear.

7 In particular, domestic companies subject to foreign competition may pursue internal restructuring involving layoffs and firm closures — though if such restructuring does not keep up with the decline in sales, which is plausible given adjustment costs in intensity of employment along with hiring and firing costs, this may imply falling productivity on the aggregate.

8 See Bernard and Jensen (2001) and Bernard and Jensen (1999), who find no evidence for a positive impact of exports on productivity for the US.

9 The 13th sector under the ISIC Classification in the Appendix, “Coke, refined petroleum products and nuclear fuel”, is excluded given that factors autonomous from those affecting other industries likely
data set is annual, and spans the period 1977–2003 (i.e. a T dimension of 25). The endogenous sector-specific variables, \( x_{it} \), included in the model are real wages (\( WAGE \)), productivity (\( PROD \)), employment (\( EMPL \)) and the capital stock (\( CAP \)). For each sector we assume that the sector-specific variables are related to manufacturing-wide variables (measured as a sector-specific weighted average of the other sectors – henceforth star variables, \( x_{it}^* \)). A set of deterministic variables, such as time trends (\( t \)), is also included, along with manufacturing-wide (weakly) exogenous variables (\( d_t \)), consisting of trade openness (\( OPEN \)) and R&D expenditure per employee (\( R&D \)) (the sources and the construction of the data are discussed in the Appendix B).

In line with Déés, DiMauro, Pesaran, and Smith (2005), we can write the GVAR more generally as a \( VARX^*(pi, qi) \) in error correction form as the vector error correction model for each sector \( i \) at time \( t \) as follows:

\[
\Delta x_t = c_{i0} - \alpha_i \beta_i^\prime [\varsigma_{i,t-1} - \gamma_i(t-1)] + \Psi_{i0} \Delta d_t + \Lambda_{i0} \Delta x_{it}^* + \Psi_{i1} \Delta d_{t-1} + \Gamma_{i} \Delta x_{i,t-1} + u_{it}
\]

where \( \varsigma_{i,t-1} = (x_{it-1}, x_{it-1}^*, d_{t-1})^\prime \). This sector specific model can now be consistently estimated separately, treating \( d_t \) and \( x_{it}^* \) as weakly exogenous \( I(1) \) with respect to the parameters of this model. The weak exogeneity assumption in the context of cointegrating models implies no long run feedbacks from \( x_{it} \) to \( x_{it}^* \), without necessarily ruling out lagged short run feedbacks between the two sets of variables. Once the individual sector models are estimated all the endogenous variables of the manufacturing industry need to be solved simultaneously.\(^{10}\)

We assume that the variables included in the sector-specific models are \( I(1) \), following Déés, DiMauro, Pesaran, and Smith (2005). While the GVAR methodology can be applied to integrated variables, this assumption allows us to distinguish between short- and long-run relations and interpret the long-run relations as cointegrated. Formal unit root tests suggest that all variables analysed can be considered as \( I(1) \), once accounting for possible structural breaks and other possible one-off factors. Augmented Dickey Fuller tests suggest that the hypothesis of a unit root cannot be rejected for most variables for most individual industries – as well as for the panel as a whole.

### 3.2 Specification and estimation of the sector-specific models

Our working assumption in this modelling exercise is that the country-specific star variables are weakly exogenous \( I(1) \) variables, and that the parameters of the individual models are stable over time. This long run forcing assumption then allows us to estimate and test the long run properties of the different country specific models separately and consistently. Both assumptions are needed for an initial implementation of the GVAR model (see Déés, DiMauro, Pesaran, and Smith (2005)). For all cases, the sector-specific models then contain the same variables, namely real wages, employment, productivity and the capital stock as endogenous variables and their starred counterparts together with trade openness and R&D as global, weakly exogenous variables. For each sector, we then estimate the corresponding cointegrating VAR model and determine the rank of

\(^{10}\)Déés, DiMauro, Pesaran, and Smith (2005) show how this can be done for a \( VAR(p) \) model.
the cointegration space. Due to data limitations, we select the lag order of the sectoral and starred variables and set both equal to one.

Given this set-up the rank of the cointegrating space for each sector is computed using Johansen’s trace and maximal eigenvalue statistics as set out in Pesaran, Shin, and Smith (2000) for models with weakly exogenous I(1) regressors, in the case where unrestricted constants and restricted trend coefficients are included in the individual country error correction models. In most cases, we find one cointegrating relationship except in the case of the textile sector where we find two. The cointegration results are based on the trace statistic (at the 95% critical value level) which is known to yield better small sample power results compared to the maximal eigenvalue statistic.

3.3 Contemporaneous effects of starred variables on their sector specific counterparts

Table 4 presents the contemporaneous effects of the starred variables on the employment of their sectoral counterparts with robust t-ratios, computed using White’s heteroscedasticity-consistent variance estimator. These values can be interpreted as impact elasticities of starred variables on their industry counterparts’ employment, or spillovers. Most of them are significant and have a positive sign. They are particularly informative as regards the linkages across sectors.

- Concerning employment, the elasticities vary across sectors by between 0.16 in other transport to 0.95% in fabricated metals. Focusing on the textile sector, representing approximately the average impact within this range, we can see that a 1% change in employment in the rest of the manufacturing sector, weighted by the importance of these sectors in the textile’s sector output, leads to an increase of 0.5% in employment in the textile sector within the same year.

- Concerning the capital stock, interestingly we observe high and often significant elasticities, implying relatively strong co-movements across sectors regarding the capital stock formation, with the highest impacts in metals, motor, chemical and food.

- Concerning productivity and real wages, elasticities are generally low and not significant. Especially on the wage side, this would suggest there is little contemporaneous ‘contagion’ across sectors as regards the wage formation process – indeed, the most significant impact elasticity is negative, for fabricated metals. This latter phenomenon may reflect a weak collective bargaining component of such industries over the period reviewed.
TABLE 4. Contemporaneous Effects on Employment of Starred Variables on the Sector-specific Counterparts

<table>
<thead>
<tr>
<th>Sector</th>
<th>Employment</th>
<th>Productivity</th>
<th>Real Wages</th>
<th>Capital Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>0.36</td>
<td>0.08</td>
<td>-0.10</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(4.30)</td>
<td>(0.56)</td>
<td>(-1.23)</td>
<td>(18.59)</td>
</tr>
<tr>
<td>Textile</td>
<td>0.51</td>
<td>-0.04</td>
<td>0.03</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>(3.32)</td>
<td>(-0.46)</td>
<td>(0.74)</td>
<td>(2.61)</td>
</tr>
<tr>
<td>Wood</td>
<td>0.56</td>
<td>0.07</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(3.96)</td>
<td>(0.91)</td>
<td>(0.13)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Paper</td>
<td>0.16</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(3.79)</td>
<td>(1.10)</td>
<td>(-0.34)</td>
<td>(6.58)</td>
</tr>
<tr>
<td>Chemical</td>
<td>0.16</td>
<td>0.05</td>
<td>0.04</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>(1.92)</td>
<td>(0.92)</td>
<td>(1.00)</td>
<td>(8.94)</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.79</td>
<td>0.09</td>
<td>-0.06</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>(5.51)</td>
<td>(0.70)</td>
<td>(-0.67)</td>
<td>(1.03)</td>
</tr>
<tr>
<td>Non-metallic</td>
<td>0.24</td>
<td>0.07</td>
<td>-0.21</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>(5.21)</td>
<td>(0.28)</td>
<td>(-1.79)</td>
<td>(9.87)</td>
</tr>
<tr>
<td>Basic metals</td>
<td>0.51</td>
<td>-0.35</td>
<td>0.19</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>(5.30)</td>
<td>(-1.89)</td>
<td>(1.26)</td>
<td>(7.34)</td>
</tr>
<tr>
<td>Fabricated metals</td>
<td>0.95</td>
<td>0.16</td>
<td>-0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Machinery</td>
<td>0.84</td>
<td>0.03</td>
<td>0.00</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>(4.02)</td>
<td>(1.39)</td>
<td>(-0.06)</td>
<td>(8.04)</td>
</tr>
<tr>
<td>Motor</td>
<td>0.86</td>
<td>0.90</td>
<td>-0.09</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>(4.65)</td>
<td>(10.68)</td>
<td>(-0.17)</td>
<td>(4.87)</td>
</tr>
<tr>
<td>Other transport</td>
<td>0.15</td>
<td>-1.00</td>
<td>0.60</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>(1.59)</td>
<td>(-1.52)</td>
<td>(1.57)</td>
<td>(0.09)</td>
</tr>
</tbody>
</table>

Note: White’s heteroskedastic robust t-ratios are given in round brackets.

4 Generalised impulse responses

To study the dynamic properties of the GVAR and to assess the dynamic responses to common shocks and spillovers from idiosyncratic sector-specific shocks, we investigate the implications of the following innovations:

- The employment and real wage impacts of a one standard error positive shock to trade openness in the US manufacturing sector
- The employment and real wage impacts of a one standard error positive shock to research and development investment
- The employment impacts of a one standard error negative shock to employment in the textile sector

In this section we make use of the Generalized Impulse Response Function (GIRF), as proposed by Koop, Pesaran, and Potter (1996) for non-linear models and developed
further in Persaran and Shin (1998) for vector error-correcting models. In the absence of strong a priori beliefs on ordering of the variables and/or sectors in the GVAR model, the GIRFs provide useful information with respect to changes in trade openness, R&D and employment. Although the approach is silent as to the specific structural factors behind the changes, the GIRFs can be quite informative about the dynamics of the transmission of shocks.

Impulse responses are presented for twenty years following the imposition of a shock, though the primarily focus on the first five years given the time span of our annual dataset. Charts 2 to 6 display the bootstrap estimates of the GIRFs. From the GIRFs and the GVAR’s eigenvalues, we can conclude that the model is stable.

4.1 Shock to US manufacturing sector trade openness

Charts 2 and 3 present the GIRFs of a positive one standard error shock to US manufacturing sector trade openness on employment and real wages in the various US manufacturing sector. A one standard error positive shock results in a 1 percentage point increase in US manufacturing trade openness.

Concerning the impact on employment, an increase in trade openness has a positive impact on employment in most sectors in contrast to the negative findings on the real wage side. On average, an increase in the trade openness by around 1 percentage point lifts manufacturing sector employment in the long run between 0 and 1%. This result is most pronounced for the other transport sector, where it lifts manufacturing sector employment by up to 4%. An examination of the dynamics of system indicates that the initial impacts are generally highest and the effect of the shock decays through time. Such a finding could be consistent with several factors, including adjustment costs in reallocating labour, frictions in varying the intensity of labour workforce in particular sectors, and a gradual loss of market share when faced with competition.

Concerning the impact on real wages, on impact the shock appears to have a negative impact for seven out of the twelve sectors considered. The short run the negative impact appears strongest in the textile, non metallic and fabricated metals sectors whereas in the long run it also becomes important in the rubber and chemical industry. Such effects however do not prevail in the food, wood, machinery and other transport sector, where wages rise in response to an increase in trade openness. An examination of the dynamics of system indicates that, somewhat in contrast to the GIRFs for employment, there is little decay in the impacts and in some cases some lags in the shock effects.

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11 The GIRF is an alternative to the Orthogonalised Impulse Responses (OIR) of Sims (1980). The OIR approach requires the impulse responses to be computed with respect to a set of orthogonalised shocks, whilst the GIR approach considers shocks to individual errors and integrates out the effects of the other shocks using the observed distribution of all the shocks without any orthogonalisation. Unlike the OIR, the GIRF is invariant to the ordering of the variables and the countries in the GVAR model, which is clearly an important consideration given various possible alternative orderings. Even if a suitable ordering of the variables in a given country model can be arrived at from economic theory or general a priori reasoning, it is not clear how to order sectors in the application of the OIR to the GVAR model.

12 The computations are carried out using a sieve bootstrap procedure as reported in Dées, DiMauro, Pesaran, and Smith (2005).

13 Such a finding for food and wood is not necessarily inconsistent with the theories such as HOS, when considering that land, in addition to capital and skilled labour, is one of the abundantly endowed resources of US.
This may correspond to some wage rigidity or, alternatively, compositional effects of a trade shock whereby skill biased rationalisation takes place.

Analysing these results in the context of the literature in 2, the finding that employment increases in response to an openness shock corroborates the basic thrust of the literature that the import competition effect is not the main driving force of manufacturing employment adjustments. At the same time, it does show that import competition has a significant effect, but then on the wage formation process. Such a finding that real wages are lowered in response to an openness shock is consistent with the predictions of the Stolper-Samuelson. As noted in Neary (2004), improved communications may have allowed large firms to fragment their operations, moving more unskilled-labor-intensive stages of production to countries where unskilled wages are low, so lowering unskilled wages in developed countries while simultaneously raising skilled wages in developing countries. Moreover, growing openness may be having an increasingly important effect on the wage formation process in the sectors analysed. This is confirmed by comparing the outcome of the GVAR over the sample period 1977-1999 with that of 1977-2003 whereby in the latter case the impulse responses to a one standard deviation shock in the US manufacturing trade openness appear to indicate a larger effect on real wages.

Concerning the impacts of this shock on the other endogenous variables of the GVAR, trade openness appears to exert a positive pressure on productivity and capital stock, hence supporting the view that trade competition induces firms to successfully introduce productivity-enhancing technologies which do not have a definite positive or negative ex-ante labour market impact.14 Such a finding was also reported in Lawrence (2000), who by using both price and quantity measures, indicates that import competition has a positive impact on US total factor productivity. This effect is mainly present in skill-intensive sectors and industries competing with developing countries.

[INSERT CHART 2 and 3]

4.2 Shock to US manufacturing sector Research and Development

Consider next the GIRFs for a one standard error negative shock to US manufacturing sector R&D. This shock is equivalent to an increase of around 5% in US manufacturing R&D spending per annum.

Employment generally increases in response to such a shock (see Chart 5), with the employment increases are more muted, and show an increase of at most 2% (again in basic metals and motor vehicles) whereas in fact for other transport equipment and the wood sector the R&D shock results in falling employment. An examination of the dynamics induced by the technological shock indicates that, after initial impact, the effect grows through time. Such a finding could relate to adjustment costs in reallocating labour and/or learning associated with the exploitation of new technologies.

14Alternatively, trade may constitute—particularly emanating from developed economies—a form of “technology transfer”, i.e. convergence in technical efficiency within individual countries over time. See Cameron, Proudman, and Redding (2005) for a recent empirical investigation of such effects between the US and the UK, with the finding that international trade raises rates of UK productivity growth through technology transfer but not innovation. See Keller and R.Yeaple (2005) for the case of the US, where it is found that FDI spillovers have a significant role in boosting productivity growth in the manufacturing sector, whereas the case for imports-related technology transfers has been less clear.
In contrast to the trade openness shock, an increase in R&D leads to an increase in real wages (as shown in Chart 4). The rise in real wages following a period of technological progress is in line with theory, indeed, such a technology shock is expected to be productivity enhancing (which is the case) and thus result in an increase in real wages. In more detail, the increase of around 5% in R&D spending per year results in real wage increases of around 0.4 to 5% in the manufacturing sector, with the lowest increases for fabricated metals and the highest for basic metals and motor vehicles. An examination of the dynamics induced by the technological shock indicates a fairly mixed profile of wage responses through time. Such a finding may possibly relate to differing skill content within the affected industries, notably heterogeneity in the adoption of new technologies or differing wage rigidities across affected industries.

Such a shock is, as in the case of the trade openness shock, also accompanied by an increase in productivity and capital stock.

[INSERT CHART 4 and 5]

4.3 Shock to US textile sector employment

The GIRF results for employment of a negative shock to US textile employment is displayed in Chart 6. Overall, a one standard error shock to US textile sector employment, which amounts to a 4% fall in the textile sector employment in the long run, reduces employment in all other sectors, by between -0.2 and 1% with the exception of the chemicals industry where employment actually increases following the fall in textile sector employment. Such a magnitude would support the notion that spillovers from idiosyncratic sectoral shocks may be important in manufacturing, but nevertheless dominated by common shocks.

[INSERT CHART 6]

5 Concluding Remarks

This paper sought to analyse the extent to which disproportionate labour market weakness in the US manufacturing sector over the last decades has derived from increasing trade openness and technological change. The empirical strategy adopted was an application of a GVAR approach, which allows for the analysis of the effects of specific exogenous shocks (trade openness and technology, proxied by R&D spending) on employment and wages in 12 subsectors of US manufacturing, along with an assessment of spillovers from the textile sector.

The results indicate that, whilst there is some heterogeneity in industry-specific impacts to the common shocks of trade openness and technology, some general trends can be inferred. Impact elasticities indicate strong intra-sectoral linkages for employment and capital stock formation, contrasting with weak linkages for what concerns real wages and productivity. An analysis of generalised impulse responses indicate that trade openness negatively affects real wages and positively affects employment, whilst
technology appears to positively affect both real wages and employment. Moreover, there is evidence of positive spillovers of employment and wage shocks across industries.

Several notable avenues for further research remain. First, an enhancement of the understanding of developments in recent years, involving *inter alia* a split of trade by partner countries so as to allow for a dichotomy of the likely differing effects of trade amongst developed economies versus between developed and emerging economies. Moreover, a further investigation using firm-level data may help understand the mechanics of such processes. Second, adding more economic structure to the approach may help to disentangle the direct and indirect (via productivity) labour market effects of trade. Third, the chosen approach could be applied to issue of technology shocks and spillovers across regions. Last, research could be broadened to consider employment dynamics in other sectors in developed economies affected by trade, notably those sectors which have seen growth in employment resulting from increased openness.
References


14
Appendices

A  Sectors covered

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<th>ISIC code</th>
<th>Industry name</th>
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<tr>
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<td>Textiles, textile products, leather and footwear</td>
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<td>Pulp, paper, paper products, printing and publishing</td>
</tr>
<tr>
<td>23</td>
<td>Coke, refined petroleum products and nuclear fuel</td>
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<td>Chemicals and chemical products</td>
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<td>27</td>
<td>Basic metals</td>
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<td>28</td>
<td>Fabricated metal products, except machinery and equipment</td>
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<tr>
<td>29-33</td>
<td>Machinery and equipment</td>
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<td>34</td>
<td>Motor vehicles, trailers and semi-trailers</td>
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<td>Other transport equipment</td>
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</table>

B  Data

PRODUCTIVITY
Definition: Value added per worker.
Units: Index, 1995=100. Value added divided by employment series (see definition below)

EMPLOYMENT
Definition: Total employees - Full Time Equivalent
Units: Thousands of units.
Source: OECD STAN Database for Industrial Analysis (last update April 2005).

EXPORTS
Definition: Exports of goods
Units: Index: 1995=100, current price export series are measured in millions USD and deflated with the aid of value added in current and constant prices per industry.
Source: OECD STAN Database for Industrial Analysis and Bureau of Economic Analysis.

IMPORTS
Definition: Imports of goods
Units: Index: 1995=100, current price import series are measured in millions USD and deflated with the aid of value added in current and constant prices per industry.
Source: OECD STAN Database for Industrial Analysis and Bureau of Economic Analysis.

OPENNESS
Definition: Sum of exports and imports of goods
Units: Index (see exports and imports).
Source: OECD STAN Database for Industrial Analysis and Bureau of Economic Analysis.

WAGE
Definition: Wages and salaries. This includes wages and salaries of employees paid by producers as well as supplements such as contributions to social security, private pensions, health insurance, life insurance and similar schemes.
Units: 1995=100, current wage series are measured in millions USD and deflated with the aid of value added in current and constant prices per industry.

RESEARCH AND DEVELOPMENT
Definition: Analytical Business Enterprise Research and Development.
Units: Millions of USD.
Source: OECD Research and Development Expenditure in Industry database (last update April 2005).

CAPITAL STOCK
Definition: An initial capital stock is calculated for 1975. For the years following investment series are accumulated and depreciated.
Source: OECD STAN Database for Industrial Analysis and Bureau of Economic Analysis.
Calculation: (see Griliches, 1979)

\[ K_{1978} = I_{1978} + (1 - \delta) \lambda I_{1978} + + (1 - \delta)^2 \lambda^2 I_{1978} + ... \]

\[ = I_{1978} \left( \frac{1}{1 - \lambda (1 - \delta)} \right) \]

with \( \lambda = \frac{1}{1 + \eta} \) and \( \eta \) is the mean annual growth rate of investments over the period 1970-1978. The depreciation rate \( \delta \) is set to equal 13.33%.

C Aggregation weights

TABLE 9. Input-output table implied weights

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Note: The first row and first column corresponds to the ISIC revision 3 code of the sector involved (see also Appendix A).
ANNEX OF CHARTS

CHART 1. US trade shares in GDP, employment, wages and productivity

Chart 1a. US real trade shares
% of real GDP

Chart 1b. US postwar payroll employment
millions of units (seas. adj.)

Chart 1c. US real hourly compensation
year-on-year growth, %

Chart 1d. US output per hour
year-on-year growth, %

Source: Bureau of Labour Statistics.
Note: Last observation refers to 2005.

Source: Bureau of Labour Statistics.
Note: Last observation refers to 2005.

Source: Bureau of Labour Statistics.
Note: Last observation refers to 2006.Q1.

Source: Bureau of Labour Statistics.
Note: Last observation refers to 2006.Q1.
CHART 2. Impulse Responses of a Positive Unit (1 std) Shock to US Manufacturing Trade Openness: Impact on Employment (Bootstrap Mean Estimates)

Source: Authors’ calculations.

CHART 3. Impulse Responses of a Positive Unit (1 std) Shock to US Manufacturing Trade Openness: Impact on Real Wages (Bootstrap Mean Estimates)

Source: Authors’ calculations.
CHART 4. Impulse Responses of a Positive Unit (1 std) Shock to US Manufacturing R&D: Impact on Employment (Bootstrap Mean Estimates)

CHART 5. Impulse Responses of a Positive Unit (1 std) Shock to US Manufacturing R&D: Impact on Real Wages (Bootstrap Mean Estimates)

Source: Authors' calculations.

Source: Authors' calculations.